# Revised Estimates of Ultrasonographic Markers for Gestational Age Assessment of Singleton Pregnancies among Indian Population

B.Priestly Shan and M.Madheswaran
Center for Advanced Research, Department of ECE
Muthayammal Engineering College,
Rasipuram 637 408, Tamilnadu, India
*priestlyshan@gmail.com, madheswaran.dr@ieee.org*

***Abstract***

*This paper presents the revised estimates of various ultrasonographic markers used in practice for estimation of gestational age among singleton Indian population. Accurate estimation of gestational age plays a vital role in efficient obstetric planning and also helps us to estimate fetal malformation or growth retardation. Incorrect estimation of gestational age can result in grave complication for the patient and liability for health care providers. But the spectacular improvement in ultrasound imaging quality in the past decade has contributed to the rapid increase in its use as a diagnostic tool in the past decade. The ultrasound based growth chart used in practice date back to 1980's. These charts have been found to estimate the gestational age with an accuracy of 2 weeks which is high compared to the state-of-the-art scanning systems. Hence in this paper an effort has been made to review the various ultrasonographic markers for fetal growth estimation and also propose revised estimates for US charts for singleton Indian population. Results indicate that using the proposed scheme, it may be possible to estimate the gestational age with an accuracy of 2 to 3 days.*

***Keywords:*** *Gestational Age Assessment – Ultrasound Fetal images – Obstetrics and Gynecology.*

## 1. Introduction

The advent of ultrasound has allowed a more direct means of assessing fetal structures and development of various organs. In the past, gestational age has been established by a combination of the historical information and physical examination. Predictions were passed based on menstrual history index, maternal sensation of fetal movement, assessment of uterine size by bi-manual examination in the first trimester, initial detection of fetal heart tones by Doppler and uterine fundal height measurement. [1-6] However it has been reported that, even in best known cases, the menstrual history index and fundal height measurement techniques are also fraught with error [7]. Timed ovulation and invitro fertilization with known date of conception are expected to estimate the gestational age accurately. However in most pregnancies the date of ovulation or conception cannot be as a accurately predicted as outlined by other methods and hence gestational age must be estimated by other methods [8-22]. In limited number of cases, basal body temperature and luteinizing hormone surge indicator are also used for estimating the gestational age with an accuracy of +/- 6 days [12]. The improvement in the field of ultrasonic imaging has made it a strong

argument for its use in obstetrics and gynecology. Presently obstetrician gynecologist is frequently called upon to perform ultrasound examination of the fetus in the first trimester. Compared to the physical examination ultrasound examination of the fetus is expected to provide the physician and healthcare professionals with estimates of greater accuracy. In the first trimester, Yolk Sac Diameter (YSD), Gestational Sac Diameter(GSD), and Crown Rump Length(CRL) measurements have been reported as the primary means of evaluating the gestational age. Fetal head, body and extremity measurements have been widely reported and found to be used in the second and third trimester [11-22]. The measured parameters include the Bi-parietal Diameter, Head Circumference, Abdominal Circumference and Femur length. Apart from these Orbital Diameters, Binocular Distance, Measurement Fetal Thorax, Embryonic Trunk Circumference, Fetal Heel Ossification, Foot Length Measurements, Transvaginal Pelvic measurements have also been reported in the literature for assessing the gestational age assessment. Recently Nasal bone length, Nuchal Translucency Thickness, Naso-Fronto Angle, Naso-Maxiliary Angle have also been reported to provide some information with respect growth in the fetus.

Obstetric charts are prepared by various paediatric associations worldwide for the use by the obstetricians and gynaecologist [7-14]. In the recent years, researchers have been focussing on population specific obstetric charts for various ethnic groups and the inter population variability in fetal growth patterns. In a study on Isralei population, 1,422 singleton pregnancies have been studied and obstetric charts based on Femur Length and Bi-Parietal Diameter have been constructed. A study on Atlantic black indigent population had revealed that the foetus had larger head, smaller abdomen and short femur lengths compared with the obstetric charts in practice. Another study on Indians and Caucasians in Britain suggest that measurements of the abdominal circumference were smaller in Indians than in White Europeans. Jacquemyn has reported differences in head circumference, abdominal circumference and femur length while investigating foetus from women of Belgium origin and migrant women from Morocco and Turkey. The fetal measurement charts in use in include the crown rump length, Bi-Parietal Diameter, occipital-frontal diameter, head circumference, femur length, abdominal circumference and humerus length. The data for the earlier of these studies have been reported to be collected on A mode, static B mode scanners and first generation real time systems with linear array transducers. Circumference measurements for both the head and abdomen studies of 1982 have been found to be performed utilizing a hand held map measurer on a ‘Polaroid’ image [11]. The margins for error were great when compared with the state of the art real time sector ultrasound systems with electronic measuring facilities currently used for fetal assessment. Due to the developments in the field of diagnostic imaging, the expectation of the obstetricians and gynaecologist has increased to have an improved obstetric chart for accurate and effective decision making. In this work, the fetal growth charts is constructed on prominent fetal parameters in first, second and third trimesters. The prime features including Yolk Sac Diameter (YSD), Gestational Sac Diameter (GSD), Crown Rum Length (CRL), Bi-Parietal Diameter (BPD), Nasal Bone length (NBL), Femur Length (FL), Trans Cerebellar Diameter (TCD), Head Circumference (HC) and Abdominal Circumference (AC) have been expected to provide accurate information about the foetus and charts have been constructed. The rest of the paper is organized as follows. Section 2 introduces the data acquisition procedures and the biometrics for the various fetal

features under investigation. Section 3 deals with the results obtained followed with conclusion and references.

## 2. Methods and Materials

### 2.1 Data Acquisition

The images of 5 to 30 weeks of gestation are obtained using high resolution scanning systems such as Wipro GE Logic 400 Curvilinear probe with transducer frequency of 3 – 5 MHz, THI Siemens machine using curvilinear probe with a transducer frequency of 2.5 MHz and Toshiba Colour Doppler scan SSD 420A (NEH1030) using a transducer with curvilinear probe containing phased array elements with frequency of 3-5 MHz. The images have been obtained on Transverse plane, Mid Sagital plane and longitudinal plane. Intracavitary probes are also employed if necessary to get a clear quality image. Necessary care has been given to preserve the shape, size and gray level distribution as it obliterates the sonographic content of information.

### 2.2 Fetal Biometrics

*Gestational Sac Diameter:* The gestational sac is the first evidence in pregnancy. It can often be recognized in the uterus after five weeks of amenorrhoea and can be located asymmetrically. It can be found as a double echogenic ring in the uterus and can be distinguishable from 5 to 6 weeks with uniform ecogenicity. A small gestational sac is usually due to a blighted ovum and is fairly a common finding. On the ultrasound examination, if the GS is found to be smaller or larger than the expected for the particular gestational age then the fetus may be treated as abnormal.

*Yolk Sac Diameter* : In the early trimester, the yolk sac can be identified as a fluid containing sac which appears as a high contrast object in the sonogram and is volumetrically larger than the early embryo. From about 7 week onwards, it is usually possible to see a round cystic structure about 4-5 mm in diameter adjacent to the fetus. The yolk sac must be visible when the gestational sac has attained 15 mm of diameter. Absence of Yolk Sac is abnormal and is associated with fetal demise. A larger Yolk Sac may cause adverse outcome on the fetus. It disappears at about the eleventh week.

*Crown Rump Length :* The Crown Rump Length (CRL) has been described as the most reliable ultrasonic parameter for determining gestational age in the first trimester. Crown Rump Length is measured at sitting height, mid brain to the lowest point of breech. Ultrasonically the CRL is measured between the fetal poles (cephalic edge) to rump and should be measured when the fetus is in a neutral position. CRL can be measured reliably form 5 to 14 weeks of gestation and it is important to assess fetal position as fetal flexion can cause variations of up to 7days.

*Head Measurements :* Fetal head measurements include the BPD, OFD, TCD and Head circumference. BPD is measured at the level of Thalamai and Cavum Septi Pellucidi. The Cerebellar hemispheres should not be visible in this scanning plane. The measurement is to be taken from the outer edge of the proximal skull to the inner edge of the distal skull. The head of the fetus may be flattened or rounded. In this case, fetal head circumference measurements may be more reliable than BPD for estimating the gestational age. This can be considered as a most reliable marker from $12^{th}$ week to $26^{th}$

week of gestation. The OCD is measured along the longest axis of the skull at the level of the Bi-Parietal diameter from outer edge to outer edge. Head circumference is measured at the same level as the Bi-Parietal Diameter around the outer perimeter of the calvarium. This measurement is not affected by shape.

Head measurements are reliable from 11 weeks gestation. Recent studies on TCD have shown that the GA can be estimated with 92% accuracy even in late second and third trimester. Hence population based studies which are being carried out by researchers are now focusing on TCD to evaluate its potential in gestational age estimation. For obtaining the TCD, the hemisphere is to be measured from the midline to the inner border of the skull. TCD measurements can be obtained reliably from 14 weeks of gestation till term.

*The Femur and Humerus Lengths*

Long bone measurements are easily obtainable from 12 weeks gestation and are particular useful when the lie of the fetus makes accurate head measurements difficult. Long bones are best imaged when perpendicular to the beam and the transducer should be rotated until the longest possible image of the bone is achieved and both cartilaginous ends are seen as blunt ends with a strong acoustic shadow posterior to the shaft. Oblique view measurements greater than fifteen degrees off the perpendicular tend to underestimate the length, as one end of the bone will appear straight, whilst the end in the far field has a curved edge.

Historically the axial resolution of an ultrasound machine is invariably better than the lateral resolution, although the newer systems have vastly superior resolution in both axes than the previous generation of machines. Between twenty-nine and thirty-four weeks of gestation, the distal femoral epiphysis (DFE) ossifies and can be easily visualized. The femur should be measured along the diaphyseal shaft, excluding the DFE. The proximal humeral epiphysis (PHE) can also ossify prenatally, usually by thirty- eight weeks and, as with the femur, should not be included in the measurement of the humeral shaft.

*Nasal Bone Length :* The fetal nasal bone can be visualized and measured after 11 weeks of gestation. A mid sagital section of the fetus including the head and upper thorax and the longitudinal axis of the Nasal bone should be obtained for accurate measurement. Echogenic lines representing the skin over nasal tip, nasal bone and the skin over nasal bridge are to be visualized in the sonogram for accurate estimation of NBL. If the Nasal bone is found absent in 11 – 12 weeks scan, a re-evaluation can be suggested by the obstetrician in 1 week.

*Abdominal Circumference :* AC can be determined at the skin line on a transverse view at the level of the junction of umbilical vein, portal sinus and fetal stomach. The abdominal imaging plane should be a true transverse cut at the level of the fetal liver and stomach, including the left portal vein at the umbilical region and ensuring that the aorta and IVC are circular. In the third trimester it may be difficult to achieve this plane due to fetal size and position. Hence dating using AC should be made as early as possible. It can be used with other biometric parameters for estimating the fetal weight and macrosomia. AC can be used as a diagnostic factor for Intrauterine Growth Retardation in which the measured data is expected to be less than the normal.

These features have been used for estimation of gestational age. The images have been pre-processed using CNLMM filter [18] and segmented using Shape sensitive derivative approach. CNLMM filter has been proved efficient in enhancing the underlying structures and Derivative segmentation scheme [31 - 40] has been utilized for segmenting the region of interest. The algorithms for these two schemes are given below.

Algorithm for CNLMM filter_____

Input :

f(x,y), the speckled image

Initialize

Window size : $W_d x W_d$ (speckle detection), $W_f x W_f$ (speckle suppression)

No if iterations : 'i' → speckle detection, 'j'→ speckle suppression 'k'→entire filter

Flag sequence : $B_i(n)$ [ : ] = '0' % '0' for good pixel, '1' for speckle detected pixel

Weighting factor (β) : 0.34 (determined by trial and error method)

Computations

# Speckle Detection #

Generate flag sequence $B_i(n)$ %initially all pixels are set to be good %

If median d(x,y) < T

$B_i(n)$ [x,y] = 0

else

$B_i(n)$ [x,y] = 1

Stop when all elements in f(x,y) has been classified

#Speckle suppression#

calculate maximum likelihood estimator at the spatial position (x,y)

$$\hat{m}(x,y) = \hat{m}_{ML}(x,y) -$$

if $B_i(n)$ [x,y] = '1', y(x,y) = m(x,y)

else if $B_i(n)$ [x,y] = '0', y(x,y) = f(x,y)

when all $B_i(n)$ [x,y] = '0', y(x,y) is the enhanced output.

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_____Algorithm for shape sensitive derivative shceme

// algorithm for optimized cost function based segmentation using topological asymptotic expansion of the cost function

// Input : v ϵ V, real valued functions, constant at image level under the universal domain

: u ϵ U, initialized class which is expected to be in the segmented domain

: $c_i$ ϵ C, set of all possible classes that can be separated out.

: K, energy minimization cost functional

// Output : $c_i$, Class from set U which minimizes the derivative of the cost function $P_{ec}$.

{ Initialize

i ← {I} ϵ Ω, the global domain

v ← {V} ϵ $H^1(\Omega)$, a subset of the global domain Ω with possible segmented images

$c_i$ ← {C} ϵ $H^2(\Omega)$, subset of Ω with predefined classes

}

Computations

{ Estimate the cost function $P_{ec}$

if derivative parameter < 0

solve $a(\varphi,\eta)$
Calculate $c_i = (C - \{c\}) U \{c + i\}$
Solve eq 2 to get the derivative condition
Perturb $c_i \rightarrow \hat{c}_i$ incrementing the center of the class from i to i+1
Calculate $\alpha$ x Ъ
}
end when the value of $\alpha$ x Ъ satisfies the convergence criteria.

## 3. Results and Discussion

The clinically obtained raw images are preprocessed to remove the speckling artifacts using CNLMM filters and segmented using shape sensitive derivative scheme. The scheme for enhancing fetal structures uses two moving kernals with a window size of 3x3 for speckle detection and suppression. If the window size is increased beyond 7, blurring has been visualized and statistical analysis show a decrease in PSNR value as the window size increases. However for contrast images with high speckling artifacts an increased window size of 5x5 at speckle suppression and detection stages has been found to be optimal and utilized. The threshold of 40 has been found optimal by trial and error method for speckle suppression. The features extracted from the processed images are tabulated in Tables 1 – 6.

**Table 1 :** Estimated Fetal Growth estimators in the first trimester

| GA (Weeks) | YSD (mm) | GSD (cm) | CRL (cm) |
|---|---|---|---|
| 5.0 | 1.4 | 1.0 | - |
| 5.3 | 1.9 | 1.3 | - |
| 6.0 | 2.4 | 1.7 | - |
| 6.3 | 2.7 | 2.0 | 6.5 |
| 7.0 | 2.9 | 2.4 | 10.2 |
| 7.3 | 3.0 | 2.7 | 13.5 |
| 8.0 | 3.1 | 3.1 | 16.3 |
| 8.3 | 3.2 | 3.4 | 20.4 |
| 9.0 | 3.4 | 3.8 | 23.7 |
| 9.3 | 3.5 | 4.1 | 28.9 |
| 10.0 | 3.6 | 4.5 | 32.7 |
| 10.3 | 3.9 | - | 35.2 |
| 11.0 | - | - | 39.1 |
| 11.3 | - | - | 43.2 |
| 12.0 | - | - | 45.6 |

**Table 2 :** Estimated Femur length

| GA Weeks | FL Measurements |
|---|---|
| 12.0 | 1.0 |
| 12.3 | 1.1 |
| 13.0 | 1.2 |
| 13.3 | 1.4 |
| 14.0 | 1.5 |
| 14.3 | 1.7 |
| 15.0 | 1.9 |
| 15.3 | 2.0 |
| 16.0 | 2.1 |
| 16.3 | 2.3 |
| 17.0 | 2.5 |
| 17.3 | 2.6 |
| 18.0 | 2.8 |
| 18.3 | 2.9 |
| 19.0 | 3.0 |
| 19.3 | 3.1 |
| 20.0 | 3.2 |
| 20.3 | 3.4 |
| 21.0 | 3.5 |
| 21.3 | 3.7 |
| 22.0 | 3.8 |
| 22.3 | 3.9 |
| 23.0 | 4.0 |
| 23.3 | 4.2 |
| 24.0 | 4.3 |
| 24.3 | 4.5 |

**Table 3 :** Fetal head Circumference measurements in the first and second trimester

| GA Weeks | HC Measurements |
|---|---|
| 13.0 | 7.8987 |
| 14.6 | 10.8571 |
| 16.2 | 13.1659 |
| 17.3 | 15.1182 |
| 19.5 | 16.9333 |
| 21.1 | 18.7565 |
| 22.7 | 20.6591 |
| 24.4 | 22.6383 |
| 26.0 | 24.6176 |
| 27.6 | 26.4463 |
| 29.3 | 27.8999 |
| 30.3 | 28.6798 |

Table 1 – 3 shows the fetal growth estimates in the first and second trimesters using Yolk Sac Diameter (YSD), Crown Rump Length (CRL) and Gestational Sac Diameter (GSD), Femur Length (FL) and Head Circumference (HC). The measurements have been made on the B mode US images as described earlier. These estimates are expected to produce an efficient estimate of the gestational age of the fetus.

**Table 5 :** Estimate of various fetal features in the second and third trimester

| GA Weeks | BPD (cm) | TCD (cm) | AC (cm) | OFD (cm) |
|---|---|---|---|---|
| 12.0 | 2.0 | - | - | - |
| 12.3 | 2.2 | - | - | - |
| 13.0 | 2.4 | - | - | 8.1 |
| 13.3 | 2.6 | - | - | 8.4 |
| 14.0 | 2.8 | 1.3 | - | 9.4 |
| 14.3 | 3.0 | 1.4 | - | 10.5 |
| 15.0 | 3.2 | 1.5 | 9.3 | 11.4 |
| 15.3 | 3.4 | 1.6 | 9.7 | 11.9 |
| 16.0 | 3.5 | 1.7 | 10.3 | 12.9 |
| 16.3 | 3.7 | 1.8 | 11.4 | 13.4 |
| 17.0 | 3.9 | 1.8 | 11.8 | 14.1 |
| 17.3 | 4.1 | 1.9 | 12.1 | 14.7 |
| 18.0 | 4.2 | 1.9 | 12.3 | 15.1 |
| 18.3 | 4.3 | 2.0 | 12.6 | 15.6 |
| 19.0 | 4.4 | 2.0 | 13.3 | 16.0 |
| 19.3 | 4.5 | 2.1 | 13.9 | 16.3 |
| 20.0 | 4.7 | 2.1 | 14.2 | 17.3 |
| 20.3 | 4.8 | 2.2 | 14.7 | 18.1 |
| 21.0 | 4.9 | 2.3 | 15.1 | 18.7 |
| 21.3 | 5.2 | 2.4 | 15.7 | 19.2 |
| 22.0 | 5.3 | 2.4 | 16.3 | 19.9 |
| 22.3 | 5.5 | 2.5 | 16.9 | 20.1 |
| 23.0 | 5.6 | 2.5 | 17.5 | 20.9 |
| 23.3 | 5.7 | 2.6 | 18.1 | 21.2 |
| 24.0 | - | 2.7 | 18.7 | 22.1 |
| 24.3 | - | 2.8 | 19.5 | 22.7 |
| 25.0 | - | 2.8 | 20.1 | 23.1 |
| 25.3 | - | 2.9 | 21.0 | 23.6 |
| 26.0 | - | 2.9 | 21.9 | 24.2 |
| 26.3 | - | 3.0 | 22.4 | 25.2 |
| 27.0 | - | 3.0 | 23.2 | 25.7 |
| 27.3 | - | 3.1 | 23.7 | 26.4 |
| 28.0 | - | 3.1 | 24.2 | 26.7 |
| 28.3 | - | 3.2 | 24.9 | 27.1 |
| 29.0 | - | 3.2 | 25.4 | 27.6 |
| 29.3 | - | 3.3 | 26.5 | 27.9 |

**Table 6** : Estimate of Nasal Bone Length in second Trimester

| GA Weeks | NBL (cm) |
|---|---|
| 15.0 | 2.5 |
| 15.3 | 2.7 |
| 16.0 | 2.9 |
| 16.3 | 3.2 |
| 17.0 | 3.3 |
| 17.3 | 3.5 |
| 18.0 | 3.7 |
| 18.3 | 3.9 |
| 19.0 | 4.1 |
| 19.3 | 4.3 |
| 20.0 | 4.8 |
| 20.3 | 5.1 |
| 21.0 | 5.6 |
| 21.3 | 5.7 |

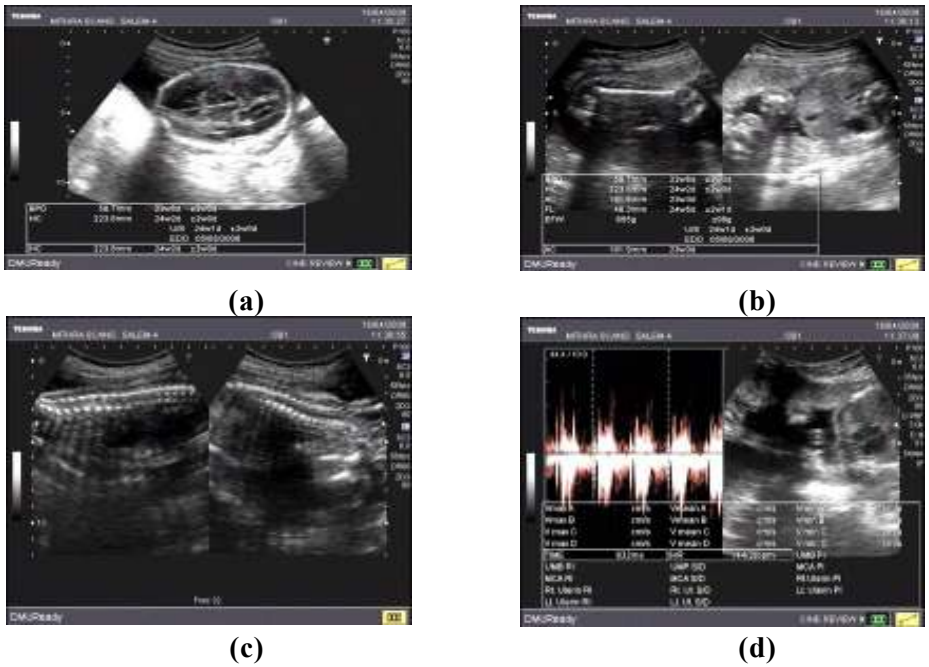
Table 6 shows the derived values of the Nasal Bone Length estimated in the second trimester. Estimation of Nasal Bonne length in the second trimester plays a vital role detecting the presence of down syndrome in the fetus. NBL along with NFA and FMA are the markers which are to be used for estimating the presence of down syndrome in the fetus. Babies born with down syndrome hardly survive upto 5 years and in cases if they survive, they are expected to develop severe chronic disorders.

Table 5 shows the estimate of Bi-Parietal Diameter (BPD), Trans Cerebellar Diameter (TCD), Occipital Frontal Diameter (OFD) and Abdominal Circumference (AC) in the second and third trimesters. For analysis, the data from subjects with uncertain LMP, suspect menstrual index, multiple gestations, malformed fetus, pregnant women with chronic disorders and women with medication which could affect fetal growth have been excluded. Measurements of Bi-Parietal Diameter (BPD) and Head Circumference were obtained from a transverse

axial plane of the fetal head showing a central mid-line echo broken in the anterior third by the cavum septii pellucid, demonstrating the anterior and posterior horns of the lateral ventricles. BPD has been measured from the outer borders of the skull and head circumference (HC) has been estimated examining the outer peripheral. Transverse Cerebellar diameter (TCD) has been measured in the sub-Occipito-Bregmatic plane of the head. The femur length (FL) was measured from the greater Trochanter to the lateral Condyle. For abdominal circumference (AC), a transverse section of the fetal abdomen was taken at the level of the stomach and the bifurcation of the main portal vein into its right and left branches.

**Table 7** Accuracy Estimation of Gestational Age prediction for Subject 1

| | | | ***Estimated GA using LMP: 22.4 Weeks*** | | |
|---|---|---|---|---|---|
| **Parameter** | Measured Value by Expert (mm) | Estimated GA by Expert (Weeks) | Estimated Value using TD approach (mm) | Estimated GA using TD approach (Weeks) | Prediction Accuracy (Days) |
| **FL** | 46.3 | 24. 5 | 42 | 23.1 | ± 4 |
| **BPD** | 58.7 | 23 | 58 | 23.2 | ± 5 |
| **AC** | 181.9 | 23.3 | 185 | 23.1 | ± 4 |
| **HC** | 223.8 | 24.2 | 220 | 23 | ± 3 |



**(a)** **(b)** **(c)** **(d)**

**Figure 1** : B-mode US images for a singleton subject showing various fetal features at 23 weeks of gestation.

**Table 8** Accuracy Estimation of Gestational Age prediction for Subject 2

***Estimated GA using LMP: 28 Weeks***

| Parameter | Measured Value by Expert (mm) | Estimated GA by Expert (Weeks) | Estimated Value using TD approach (mm) | Estimated GA using TD approach (Weeks) | Prediction Accuracy (Days) |
|---|---|---|---|---|---|
| **FL** | 61.5 | 31.4 | 58.4 | 28.1 | ± 1 |
| **BPD** | 75.7 | 28.6 | 750 | 28.2 | ± 2 |
| **AC** | 261.2 | 31.0 | 256.1 | 28.2 | ± 2 |
| **HC** | 287.2 | 32 | 275 | 28.1 | ± 1 |

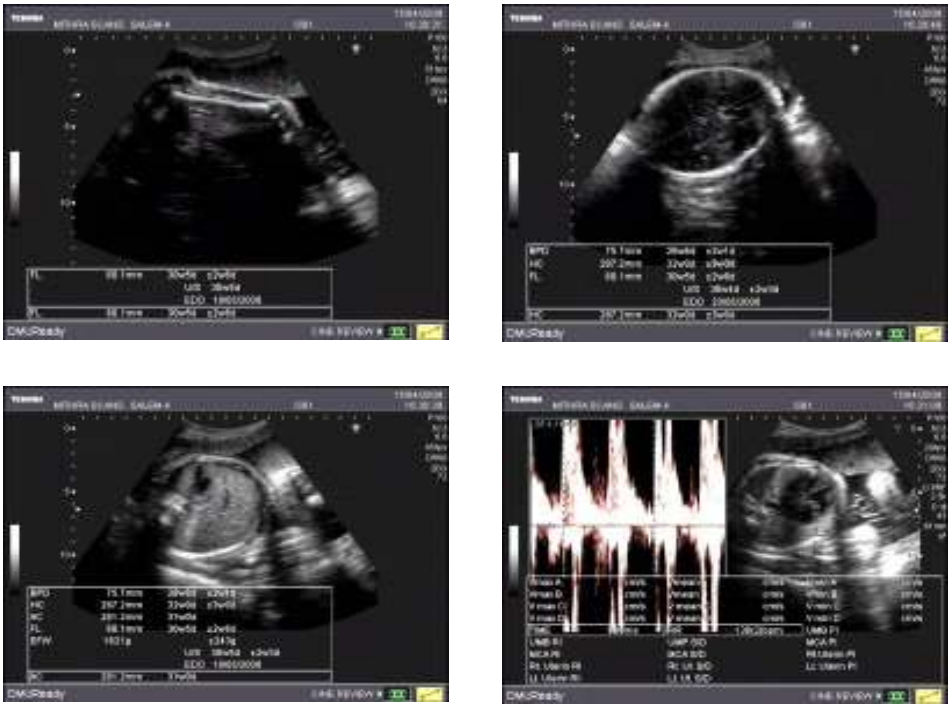


**Figure 2** : B-mode US images for a singleton subject showing various fetal features at 28 weeks of gestation.

Table 7 and 8 shows the clinical validation of the study carried out for various subjects. Figures 1 and 2 shows the B-mode US scanned images of singleton pregnancies at 23 and 28 weeks of gestation. Studies reveal that using the present scheme, it may be possible to estimate the gestational age with an accuracy of 2 to 3 days.

## 4. Conclusion

In this paper, a dynamic approach for measuring fetal features using improved Image processing techniques has been presented. The modified CNLMM filter has been used for Despeckling preserved the edges and has shown to give a high SNR. The region of interest has been enhanced while retaining the clinically potential areas. The segmentation algorithm based on topological derivative with its optimized energy cost functional has segmented the features and enhanced the edges for accurate measurement. Obtained results show that its possible to predict the gestational age with a deviation of as low as ± 2 to ± 3 days using the derived charts.

## 5. References

1. Peter W.Callen, M.D., "Ultrasonography in Obstetrics and Gynecology," W.B.Saunders Company, 1983.
2. Palmer P E S, "Manual of Diagnostic Ultrasound", World Health Organization, 1995.
3. Vinkesteijn A.S.M, Jansen C.L.R., Los F.J., Mulder P.G.H, "Fetal Transcerebellar Diameter and Chromosomal Abnormalities" Journal of Ultrasound in obstetrics and Gynecology, Vol 17, No 6, pp 502 – 505, 2001.
4. Malik R, Pandya VK, Shrivastava P, "Gestational age estimation using transcerebeller Diameter with grading of fetal cerebellum and evaluation of TCD/AC ratio as a gestational age independent parameter", Indian Journal of Radiology and imaging, Vol 13, Issue 1, PP 95 – 97, 2003.
5. Martin R Chavez, Cande V Ananth, John C Smulian, "Fetal TCD measurement for prediction of gestational age at the extremes of fetal growth", Journal of Ultrasound Medicine, Vol 26, Pp 1161 – 1171, 2007.
6. Morris J K, Mutton D E, Alberman, "Revised estimates of the maternal age specific live birth prevalence of down syndrome", Journal of Medical Screen, Vol 9, pp 2-6, 2002.
7. Frank P hadlock, Russell L Deter, Ronald, Seung, "Estimating Fetal age : Computer assisted analysis of multiple fetal growth parameters" Journal of radiology, 152, pp 297 – 501, 1984.
8. Carol B Benson, Peter Doubilet, Daniel, "Intrauterine growth retardation : Predictive value of US criteria for antenatal diagnosis", Journal of Radiology, Vol 160, pp 415 – 417, 1986.
9. Juozas K, Eileen M W, Patrick R, Roland Z, Renate H, Joseph W, "Fetal Ultrasound biometry : Abdomen and femur length reference values" British Journal of Obstetrics and Gynecology, Vol 106, pp 136 – 143, Feb 1999.
10. Mohammed Aziz, Mohammed Iqbal Khattak, Arbab Abdul Wadood, "Gestational Age Assessment : Role of CHL and CRl of term in Neonates in Pakistan", The Professional, Vol 11, No 2, pp 203 – 207, 2004.
11. Verburg BO, Steegers, De Rider, Snijders, Smith, Hofman, Moll, Jaddoe, Witteman, "New Charts for ultrasound dating of pregnancy and assessment of fetal growth : longitudinal data from a population based cohort study", Journal of ultrasound obstetric and gynecology, Vol 31, Issue 4, pp 388 – 396, 2008.
12. Nathan Jeffery, "Cranial Base angulations and growth of the human fetal pharynx" The anatomical Accord, part A, 284A, pp 491 – 499, 2005.
13. Frank P H, Yogesh P S, Donna J K, Math B, Josuha V L, "Fetal crown Rump Length : Re-evaluation of relation to menstrual age (5 – 15 weeks) with high resolution real time US", Journal of Radiology, Vol 182, pp 501 – 505, 1992.
14. "ACR practice guideline for the performance of obstetrical ultrasound", ACR practice guideline, obstetrical ultrasound, pp 1093 – 1101, 2007.

15. Chalana et.al, "Ultrasound System for automatically measuring fetal head size", United States Patent, Patent No : 5605155, 1997.
16. Dua a, Schram C, "An investigation into the applicability of customized charts for the assessment of fetal growth in antenatal population at Blackburn, UK", Journal of Obstetrics and Gynecology, Vol 26, No 5, pp 411 – 413.
17. Keramidaris, Hooper, Harding, "Effect of gestational age in fetal lung following tracheal Obstruction", Journal of experimental Lung Research, Vol 22, No 3, pp 283 – 298, 1996.
18. Sturla H E, Per Grottum, Per-Hakan, Karel Marsal, "Prediction of fetal growth deviation by ultrasonic biometry", Acta Obstetricia et gyneacologica Scandinavicia, Vol 61, No 2, pp 53 – 58, 1982.
19. Kamini A Rao, "An Introduction to Genetics and Fetal Medicine", Jaypee brothers Medical Publications, 1996.
20. Edund Hui Ng (2005), 'Speckle Noise Reduction Via Homomorphic Elliptical Threshold Rotations in Complex Wavelet Domain', A MS ThesisPresented to University of Waterloo, Canada.
21. Gustavo Carneiro, Bogdan Georgescu, Sara Good, (2008), 'Knowledge-based automated fetal biometrics using syngo auto OB measurements', Whitepaper ACUSON S2000.
22. Gustavo Carneiro, Ph.D., Bogdan Georgescu, Ph.D., Sara Good, RDMS, (2008)" Knowledge-based Automated Fetal Biometrics", Whitepaper, ACUSON S2000, Siemens Medical Solutions.
23. C.Huissoud, C.Bisch, K.Charrin, R.CRudigoz, L.Guibaud, (2008), 'Prenatal diagnosis of partial lumbar asoma by two and three dimensional ultrasound computed and tomography:embryological aspects and perinatal management', Wiley InterScience, vol.32, pp.579-589.
24. Mark Alden Haun, " New approaches to aberration correction In Medical Ultrasound Imaging" PhD Thesis, University of Illinois at Urbana-Champaign, 2003.
25. Nicolaides KH, Azar G, Byrne D, Mansur C, Marks K., Fetal nuchal translucency: ultrasound screening for chromosomal defects in first trimester of pregnancy, *BMJ 1992;304*:pp 867–889.
26. Nicolaides KH., "Nuchal translucency and other first-trimester sonographic markers of chromosomal abnormalities", *Am Journal of Obstet Gynecol, 191*: pp45–67, *2004*.
27. Jan Odegard,Anders Osten, "Automatic diagnosis of ultrasound images using standard view planes of fetal anatomy," Norwegian University of Science and Technology, 2006.
28. J.Rigau, M.Fexias, M.Sbert, A.Bardera, I.Boada, "Medical image segmentation based on mutual information maximization", 2002.
29. Jiankang Wang and Xiaobo Li, "A System for Segmenting Ultrasound Images," *Pattern Recognition* proceedings 14th international conference, vol. 1, pp. 456-461, 1998.
30. Kypros H. Nicolaides, "11-13 weeks scan", Fetal Medicine Foundation (FMF), London, 2004.
31. Khandpur.R.S, " Handbook of Biomedical Instrumentation", Tata McGraw Hill, New Delhi, 2003.
32. Larrabide, Antonio, Masmoudi, et.al, "Topological Derivative as a tool for image processing", Part I, National Laboratory for Scientific Computation, Petr´opolis, Brazil, 2006.
33. Larrabide I, Feijoo R A, Novotny A A, Taroco E and Masmoudi M, "An Image Segmentation Method Based On A Discrete Version Of The Topological Derivative," 6th World Congress On Structural And Multidisciplinary Optimization, Jun 2005.
34. Larrabide.I, A. A. Novotny, R. A. Feijo, and E. Taroco, "A medical image enhancement algorithm based on topological derivative and anisotropic diffusion," in Proceedings of the XXVI Iberian Latin-American Congress on Computational Methods in Engineering - CILAMCE 2005 - Guarapari, Esprito Santo, Brazil, 2005.
35. Novotny.A, R. Feij´oo, E. Taroco, and C. Padra, "Topological sensitivity analysis," Computer Methods in Applied Mechanics and Engineering, vol. 192, pp. 803–829, 2003.
36. S. Osher and J. A. Sethin, Fronts propagating with curvature-dependent speed: Algorithms based on Hamilton–Jacobi formulation, *J. Comput. Phys.* **79**, 1988, 12–49.
37. P.C.Pedersen, V.Mitra, J.Dev, "Boundary detection 3D Ultrasound reconstruction using nearest neighbour map,"2004.
38. Peter W.Callen, M.D., "Ultrasonography in Obstetrics and Gynecology," W.B.Saunders Company, 1983.
39. Russell E Muzzolini, "Segmentation of Ultrasound Images using Texture Discrimination" PhD thesis, Department of Computer Science, University of Saskatchewan, Saskatoon, 1991.

40. B.Priestly Shan and M.Madheswaran, "Nonlinear Cost Optimization Scheme for Feature Segmentation in Second Trimester Fetal Images" Proceedings of the Seventh ACS/IEEE International Conference on Computer Systems and Applications (AICCSA-09), Rabat, Morocco, May 10-13.
41. Russel.E.Muzzolini, "A volumetric approach to segmentation and texture characterization of ultrasound images," Phd paper, University of Saskatchewan, 1997.
42. S.Jardim and M. Figueiredo, "Automatic contour estimation in fetal ultrasound images," Portugese Foundation of Science and Technology, 2000.

## Authors

**B.Priestly Shan** received his bachlors degree in Electronics and Communication Engineering from Manonmaniam Sundaranar University, Tirunelveli, India in the year 2003 and M.E Degree in Communication Systems from Anna univeristy Chennai, India in the year 2006. At present, he is working as Assistant Professor in the Department of Electronics and Communication Engineering of Muthayammal Engineering College, Rasipuram, India. He has authored over Twenty five research publications in International and National Journals and Conferences. His area of Interest includes Signal Processing, Image Processing and Bio medical Engineering. He is a memder of various professional societes including Institute of Electrical and Electronics Engineering, Institute of Electonics and Telecommuication Engineering and Medical Computer Society of India. He is also the secretary of IEEE India Circuits and Systems Society Chapter and Executive member for IEEE India Electron Devices Society.

**M.Madheswaran** received the BE Degree from Madurai Kamaraj University in 1990, ME Degree from Birla Institute of Technology, Mesra, Ranchi, India in 1992, both in Electronics and Communication Engineering. He obtained his PhD degree in Electronics Engineering from the Institute of Technology,Banaras Hindu University, Varanasi, India, in 1999. At present he is a Principal of Muthayammal Engineering College, Rasipuram, India. He has authored over Seventy five research publications in International and National Journals and Conferences. Currently he is the chairman of IEEE India Electron Devices Society Chapter. His areas of interest are theoretical modeling and simulation of high-speed semiconductor devices for integrated optoelectronics application, Bio-optics and Bio-signal Processing. He was awarded the Young Scientist Fellowship (YSF) by the State Council for Science and Technology,TamilNadu, in 1994 and Senior Research Fellowship (SRF) by the Council of Scientific and Industrial Research (CSIR), Government of India in 1996. Also he has received YSF from SERC, Department of Science and Technology, Govt. of India. He is named in Marquis Who's Who in Science and engineering in the year 2006. He is a Member of Institute of Electrical and Electronics Engineers, Fellow of Institution of Electronics and Telecommunication Engineers, Member of Indian Society for Technical Education and Member of Institution of Engineers.